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(54) **Ion source.**

(57) An ion source in which a gaseous material, the source of the ions, is excited to a plasma state by means of a radio frequency electromagnetic field. The wall of the chamber containing the plasma is maintained at a high temperature and there is provided a solenoidal or radial multipolar electric field thereby to cause the ion source to produce atomic rather than malecular ions.

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Ion Source

The present invention relates to ion sources.

Ion sources are known in which a gaseous material, ions of which are to be generated, is excited to a fully ionised, or plasma, state by means of radio-frequency alternating fields. The desired ions are then extracted from the source by means of an electric field produced by one or more extraction electrodes.

Such sources as are known, however, produce predominantly beams of molecular ions, and for some purposes, for example, the production of insulating regions in semiconductor substrates for use in the production of very large scale integrated circuits, or regions which need to have specific types of electrical conductivity in such circuits, molecular ions are deleterious.

An object of the present invention therefore is to provide a radio frequency plasma ion source which produces predominantly atomic ions.

According to the present invention there is provided an ion source, comprising a chamber which can be evacuated, means for introducing into the chamber in a gaseous state a material ions of which are to be provided by the source, means for applying an alternating electromagnetic field to the gaseous medium whereby it can be excited to a plasma state, means for applying an electric field to extract ions from the plasma, means for maintaining the walls of the chamber at an elevated temperature, and means for applying a solenoidal or radial multipolar magnetic field to a plasma within the chamber.

The energy required to heat the walls of the chamber may be derived from the plasma or applied from an external source.

By allowing the walls of the chamber to reach a temperature in the region of 600°C and applying the magnetic field to the plasma, the electron temperature within it can be raised to a value such that the molecules of the plasma material are dissociated and prevented from recombining. Thus the ion source will produce predominantly atomic ions. Any unwanted molecular ions can be removed by means of a magnetic analyser.

Preferably, the ion source includes an extractor electrode having a plurality of parallel slits therein so as to produce a plurality of parallel individual beams.

The invention will now be described, by way of example, with reference to the accompanying drawings, in which

Fig 1 is a schematic representation of one embodiment of the invention, and

Fig 2 is a schematic representation of a second embodiment of the invention.

Fig 3 is a diagrammatic representation of an ion beam generator embodying the invention.

Referring to Figure 1, an ion source comprises a chamber 1 some 700 mm in diamater the wall 2 of which is made of quartz. In the wall 2 are a first port 3 by means of which the chamber 3 can be evacuated, and a second port

4 by means of which a volatile or gaseous material, ions of which are to be provided by the source, can be introduced into the chamber 1. Surrounding the chamber 1 is a coil 5 through which an electric current can be passed from a radio-frequency power source 6 of a known type, which will not be described further. The frequency and power output of the power source 6 are such that the material introduced into the chamber 1 is fully excited into the plasma state. Also connected to the coil 5 is a second power source 7 which is adapted to provide a steady solenoidal magnetic field 8 in the region of the major part of the wall 2 of the chamber 1. Two coils 9 and 10, respectively are provided to isolate the power source 7 from the radio frequency current in the coil 5. Situated within the chamber 1 is a quartz plate 11 the function of which is to prevent electrons from impinging on those parts of the wall 2 of the chamber 1 to which the solenoidal magnetic field 8 does not reach.

A metal plate 12 defines an exit hole for ions produced by the source, and also acts as an extraction electrode.

In use the wall 2 of the chamber 1 becomes heated to a temperature of several hundred degrees centigrade as a result of bombardment by the consituents of the plasma within the chamber 1. The operating temperature of the wall 2 of the chamber 1 is not critical but does have an optimum value which depends on the material of the plasma in the chamber 1. For example, if the gaseous material is oxygen at a pressure of about 0.7 m Torr, then a wall temperature of about 600°C is appropriate. If necessary, external heating or cooling means can be provided. In the drawings cooling coils 13 are shown.

In a plasma most of the tendency for the electrons and ions to recombine occurs at its periphery. Also, in these cooler regions neutral atoms recombine to form molecules. The hot wall 2 of the chamber 1 and the magnetic field 8 control both the distribution of the electron temperature in the plasma and also the flux of ions to the wall 2 of the chamber 1. The net result is to enhance greatly the number of atomic ions produced by the source compared with the output from a conventional plasma discharge ion source.

Figure 2 shows a second embodiment of the invention in which the magnetic field 8 is provided by a number of magnets 21 and is multipolar in form. The ion source operates in the same way as the first embodiment and therefore will not be described further. Those components which are common to both embodiments have the same reference numerals.

If the source is to be used to produce ions of a material which normally is in a solid or liquid form then the port 4 can be connected to a furnace in which the material can be vapourised.

Referring to Fig 3 of the drawings, an ion beam generator embodying the present invention consists of a vacuum chamber 30 which has two ports 32 and 33 through which it can be evacuated. One end of the vacuum chamber 30 is bolted to a base plate 25 which has a central hole 26 in it through which an ion beam 27 can enter the vacuum chamber 1.

Positioned in the path of the ion beam 27 is an electromagnet assembly 28. The electromagnet assembly 28 provides a first magnetic field 29' which is directed out of the plane of the paper on which the figure is drawn, and

a second magnetic field 29'' directed in the opposite direction. The electromagnet assembly 28 has a core 31 which is in the form of a complete loop which is cut to provide two pairs of pole pieces 34 and 35. Appropriately connected pairs of coils 14 and 15, respectively, are wound upon the pairs of pole pieces 34 and 35. The pair of pole pieces 35 carries a number of water-cooled plates 16 which are so positioned as to intercept those components of the ion beam 27 which have mass-charge ratios other than that of the singly ionised monatomic species the magnetic analyser is intended to produce. The pair of pole pieces 35 also carry a structure 17 which defines an exit slit 18. The plates 16 and the structure 17 are water-cooled. Mounted on the vacuum chamber 30 opposite the incoming ion beam 27 is a beam dump 19 which is arranged to intercept and absorb the energy of the ion beam 27 in the absence of any magnetic fields being produced by the electromagnet assembly 28.

The ion beam 27 is produced by an ancilliary assembly 20 attached to the vacuum chamber 30. The assembly 20 includes a radio-frequency plasma ion source 21 as described with reference to Figs 1 and 2. Associated with the plasma ion source 21 are three grid holders and extraction electrodes 22 which between them define a series of parallel recangular cross-section beamlets which together make up the ion beam 27. The longer axes of the beamlets are aligned parallel with the magnetic fields 29' and 29''.

In use, the magnetic field 29' diverts the beam 27 to its right as shown, and separates it into its constituent ions having differing mass-charge ratios in the normal way. Ions having considerably different mass-charge ratios impinge on, and are absorbed by, the plates 16. Ions

having a relatively small spread in mass-charge ratio centred on the desired value are deflected in the opposite direction by the second matgnetic field 29^{11} and are brought to foci at the structure 17. The slit 18 allows only those ions having the exact mass-charge ratio desired to pass through and emerge as a sharply-diverging beam 23 of rectangular cross-section of the desired ion species. All the other ions are intercepted by the structure 17, which also is water-cooled.

The emerging ion beam 23 may show some residual structure arising from the beamlets. If this is so, and its effects are judged to be undesirable, then this can be reduced, or removed by a number of methods, for example:

a) by modulating the energy of the input beam 27,

b) by modulating the magnetic fields 29' and 20'' or

c) by electrostatically sweeping the ion beams during their passage through the field-free region between the magnetic fields 29' and 29'' or

d) by allowing a controlled measure of divergence in at least one of the beamlets which make up the ion beam 27.

Claims

1. An ion source, comprising a chamber which can be evacuated, means for introducing into the chamber in a gaseous state a material ions of which are to be provided by the source, means for applying an alternating electromagnetic field to the gaseous medium whereby it can be excited to a plasma state, means for applying an electric field to extract ions from the plasma, wherein there is provided means (13) for maintaining the walls of the chamber at an elevated temperature, and means 5, 7, 9, 10, 21) for applying a solenoidal or radial multipolar magnetic field (8) to a plasma within the chamber.

2. An ion source according to claim 1 wherein the means (22) for applying an electric field to extract ions from the chamber includes an electrode having a plurality of parallel slits formed in it so as to provide a plurality of elongated parallel beamlets.

3. An ion source according to claim 1 or claim 2 wherein the means (13) for maintaining the walls of the chamber at a high temperature is adapted to maintain the walls of the chamber at a temperature of approximately five hundred degrees celsius.

4. An ion source according to any of claims 1 to 3 in association with a magnetic analyser (28, 14, 15, 16, 17, 18, 34, 35) adapted to select only ions having a predetermined mass to charge ratio.

5. An ion source and magnetic analyser according to claim 4 wherein the magnetic analyser (28, 14, 15, 16, 17, 18, 34, 35) includes means (4, 15, 34, 35) for providing two anti-parallel magnetic fields (29' 29") and the said beamlets of ions are arranged to pass orthogonally through

them sequentially, the first magnetic field (29') serving to select ions of the given mass to charge ratio, and the second magnetic field (29") serving to bring the selected ions to a focus to form a single divergent beam of ions (23).

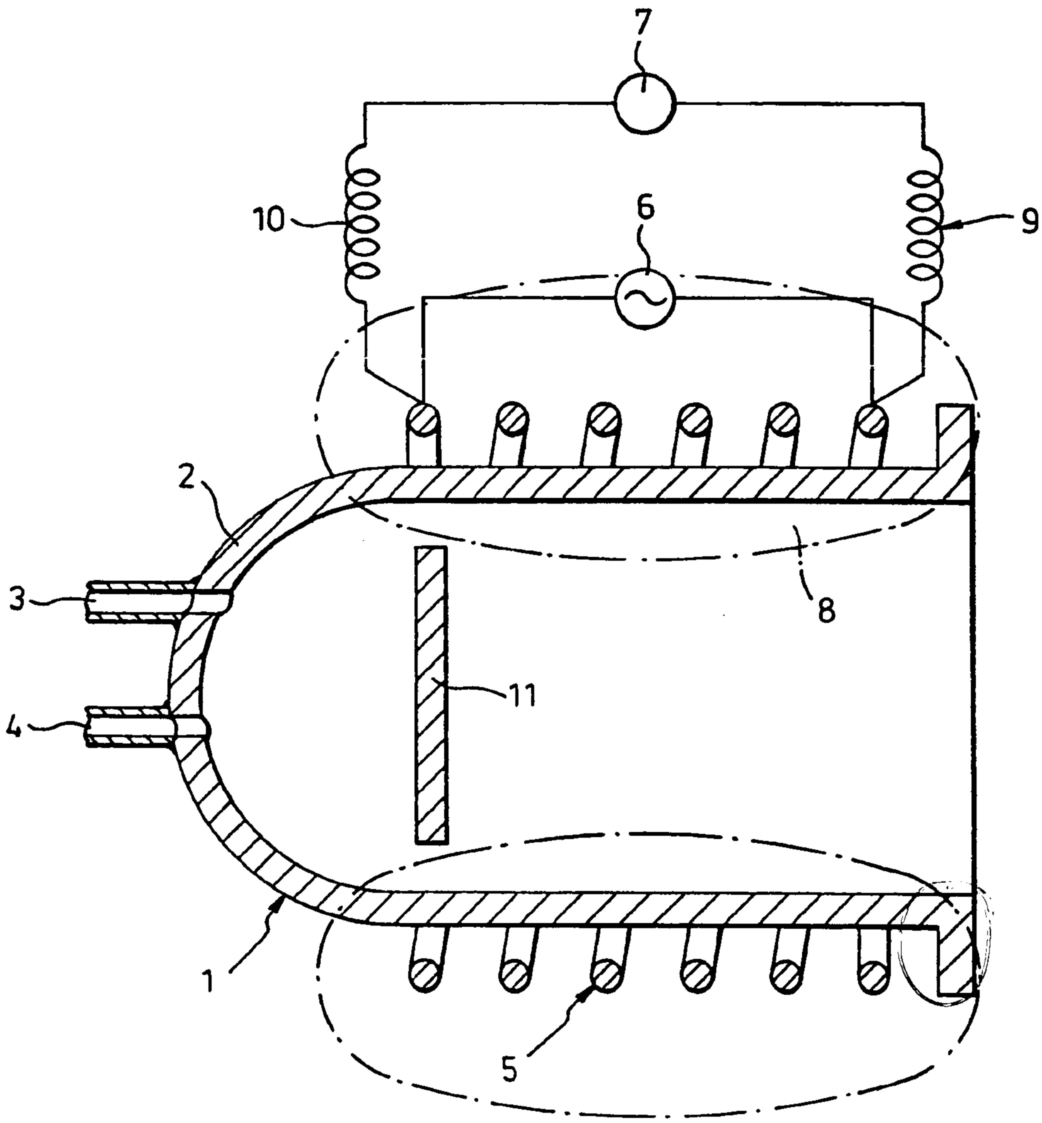

Fig. 1.

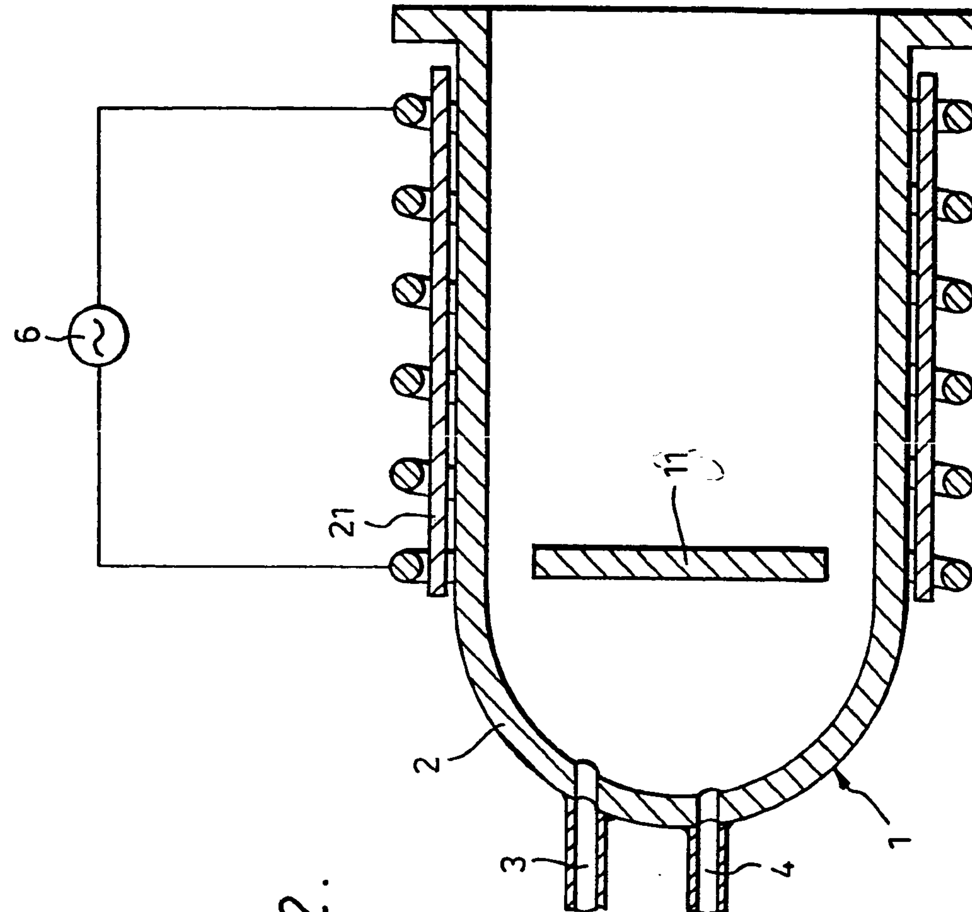

Fig. 2.

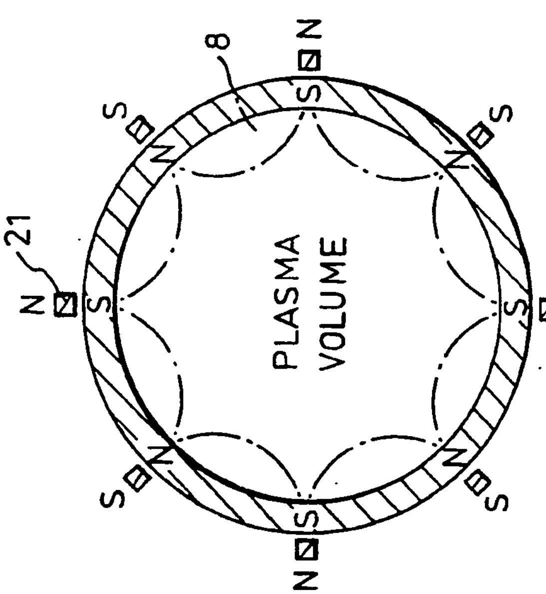

Fig.3.